NASA AMES
Virtual Airspace Modeling and Simulation (VAMS)

Air Traffic Management System Development & Integration (ATMSDI)

VAMS TIM #2

Airspace Concepts Evaluation System: Build 1 Modeling

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Outline

- Overview of ACES Build 1 models
- Model descriptions
  - Requirements
  - Build 1 approach

Modeling Functionality Overview

- Flight
  - Trajectory propagation
  - Pilot model
- ATCSCC
  - Congestion alert
  - Ground delay program
  - Ground stop program
- ARTCC TFM
  - Impose TFM restrictions
    - » Intra Center
    - » Inter Center
    - » TRACON

Modeling Functionality Overview (cont.)

- ARTCC ATC
  - Meet TFM restrictions
  - Maintain separation (CD&R)
- TRACON TFM
  - Impose TFM restrictions
    - » Airport
    - » Center
  - Receive TFM restrictions
- TRACON ATC
  - Set TRACON delay

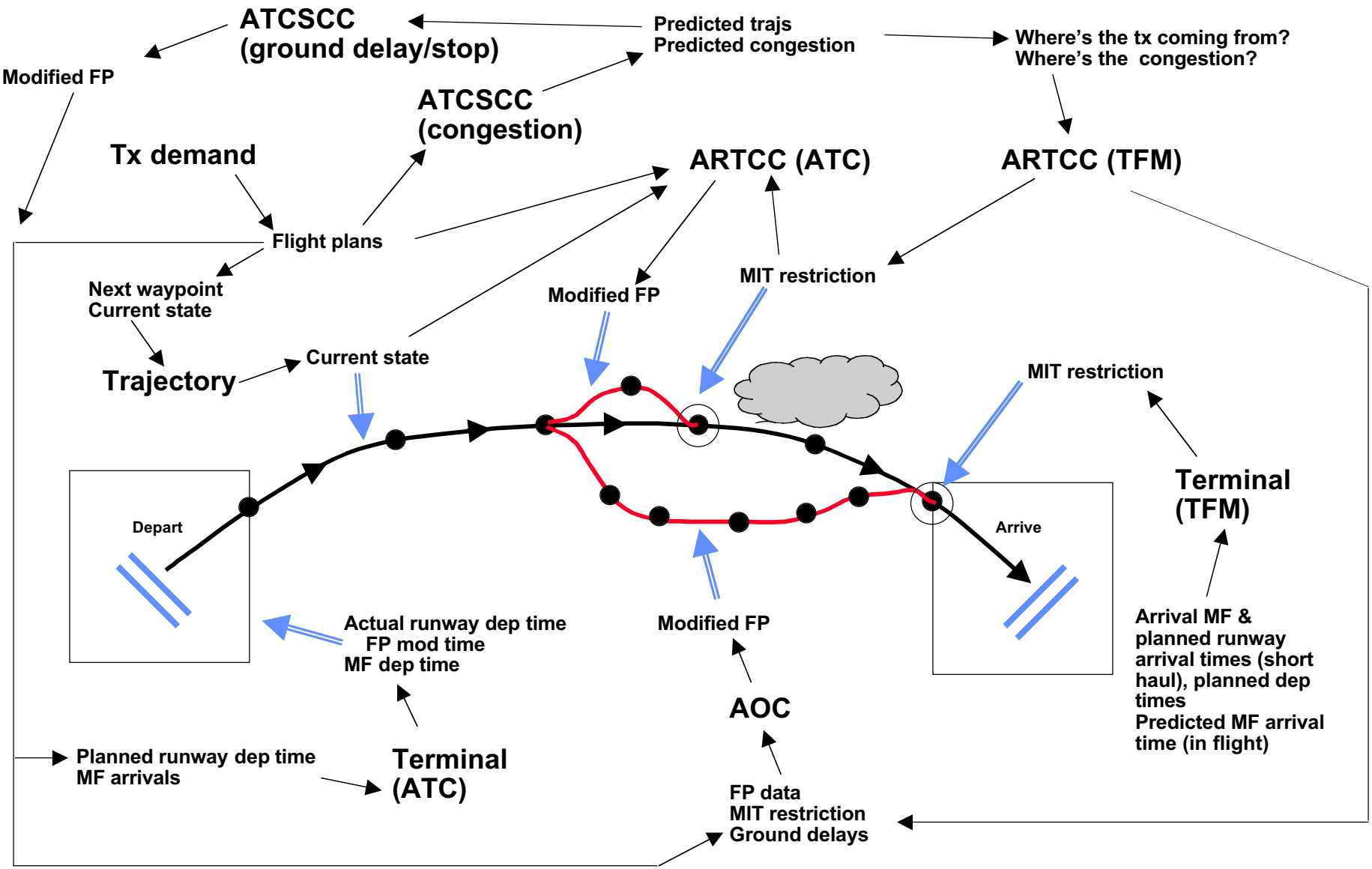
Modeling Functionality Overview (cont.)

- Airport TFM
  - Impose TFM restrictions
    - » TRACON
- Airport ATC
  - Runway queing
- Weather
  - Four dimensional winds
  - Convective weather

Modeling Functionality Overview (cont.)

- AOC traffic demand
  - Generate a day of traffic
- AOC flight control
  - Cancellations
  - Delays

Overview of Model Interactions



Model descriptions

Trajectory Propagation Requirements

The flight agent shall:

- model the enroute aircraft trajectory including position, velocity and fuel burn.
- incorporate the effects of winds in calculating the aircraft trajectory in the enroute environment.
- model the terminal area aircraft trajectory including flight time and fuel burn.
- model nominal flight times for transitioning terminal airspace unless modified by the TRACON ATC agent to ensure separation of aircraft.

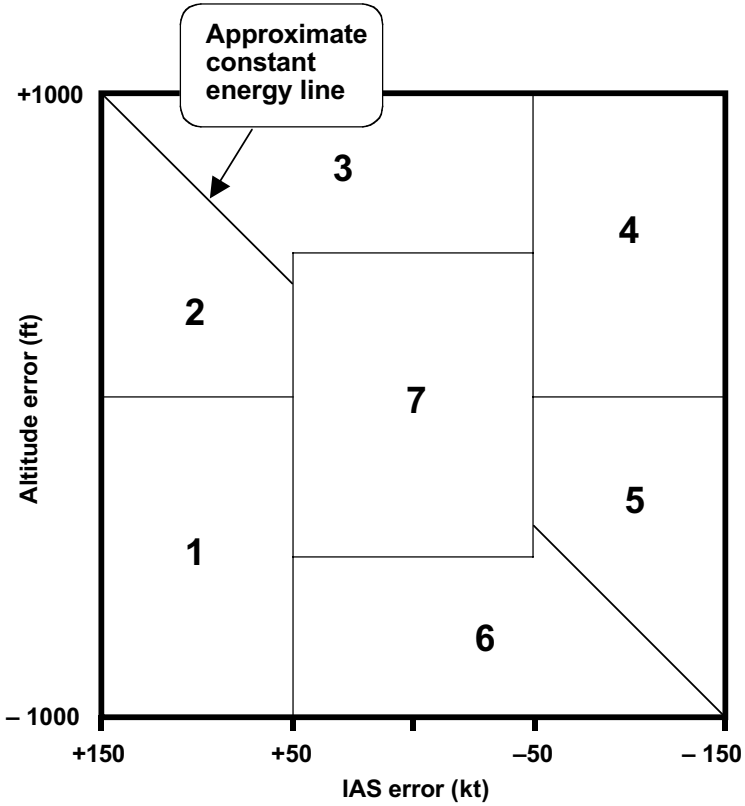
Trajectory Propagation Requirements

The flight agent shall:

- utilize a nominal airport departure taxi time unless additional delays are assigned by the airport due to airport congestion (queing delay).
- conform to nominal climb and decent profiles unless directed by Air Traffic Control.
- model at least 50 aircraft types
- provide the following data for data collection on each flight: airline, flight ID, departure airport, arrival airport, aircraft type ID, actual gate departure time, actual runway departure time, actual departure meter fix time, actual arrival meter fix time, actual runway arrival time, actual gate arrival time, fuel burned

Trajectory Propagation: MPAS

- **Trajectory modeling**
  - Model aircraft trajectory including position, velocity and fuel burn
- **MPAS model**
  - Developed for NASA and FAA
  - 4 degree-of-freedom (DOF) model
    - » Three translational DOFs plus aircraft roll angle
  - Elliptical earth model
    - » WGS-84
  - Pilot model for horizontal- and vertical-plane maneuvers



Vertical Plane Control Logic

ATCSCC Requirements

The ATCSCC agent shall:

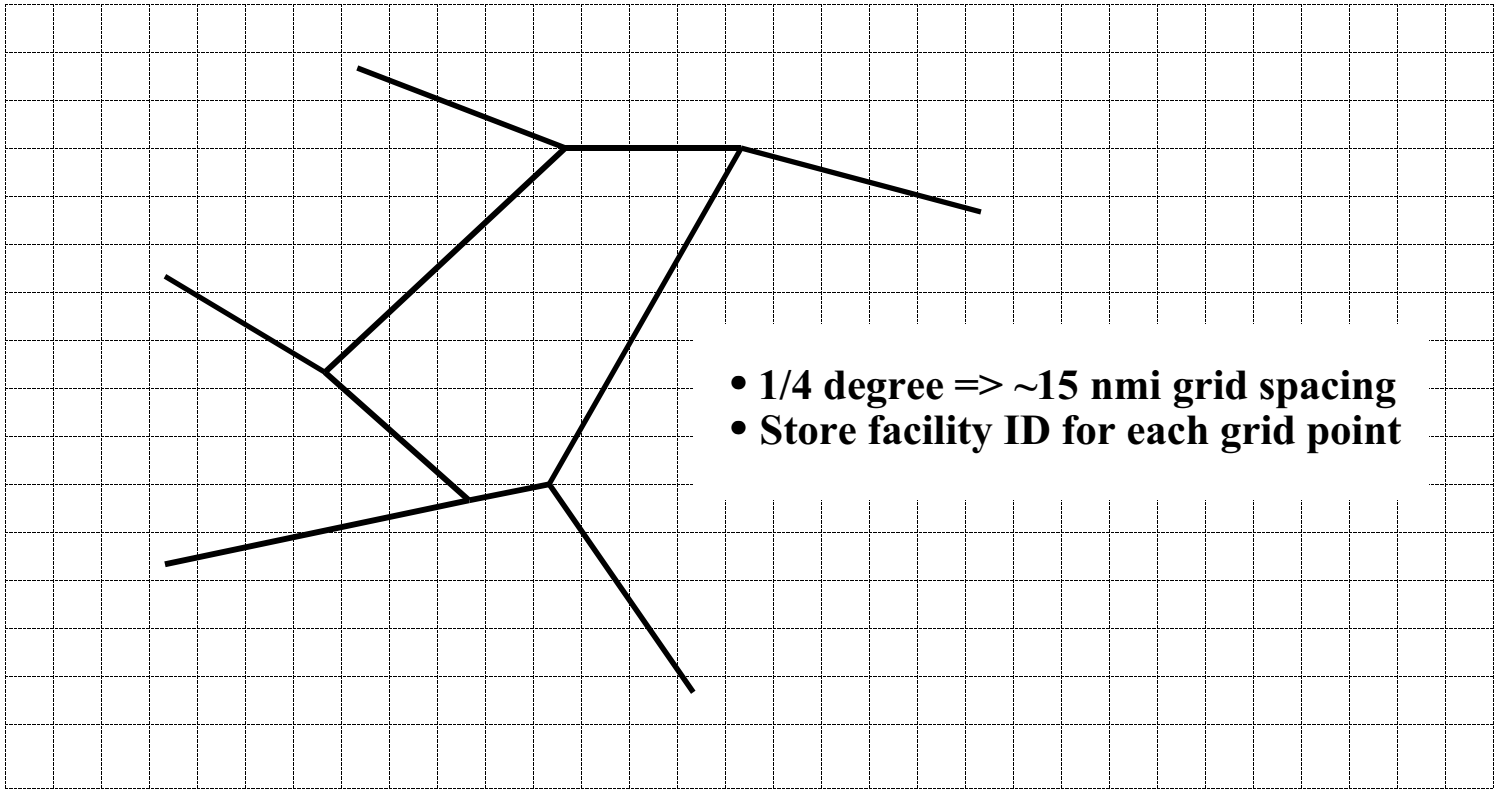
- model the Monitor Alert function.
- model the Ground Stop Program.
- model the Ground Delay Program on a first-come first-serve basis.
- provide the following data for data collection: Monitor Alerts (time issued, time of alert, duration, location); Ground Stop Programs (time issued, start time, duration, facility); and Ground Delay Program (time issued, aircraft IDs, time delays)

ATCSCC Monitor Alert

- Model the Monitor Alert function which predicts and warns of overloaded sectors
- Track/predict sector transit profile for all flights
  - Approximate at one-minute intervals
- Predict maximum instantaneous sector counts in 15 minute intervals
  - Approximate as maximum of fifteen consecutive one-minute sector counts
- Send congestion alert message when predicted sector loading exceeds capacity

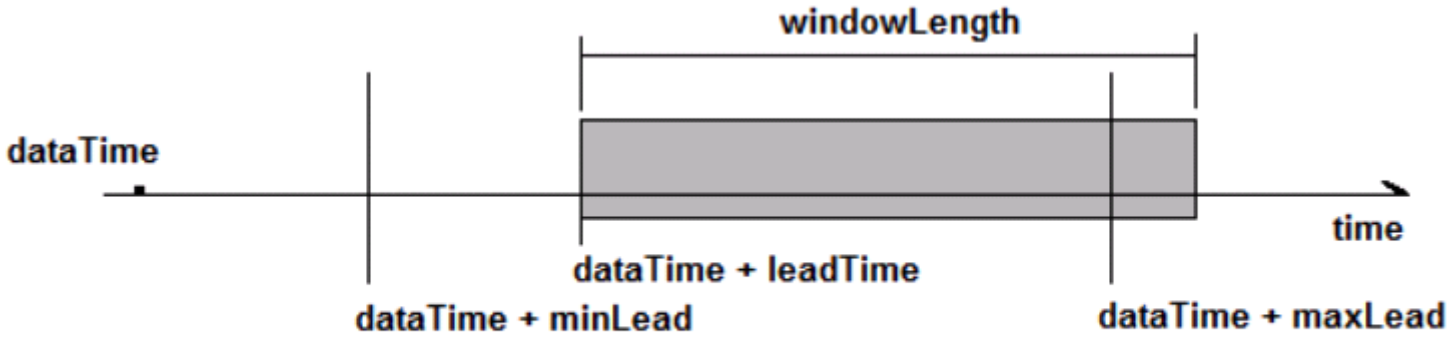
Spatial Lattice

- Provides table lookup for ARTCC and sector identification



ATCSCC GDP

- Ground delay program
  - Delay aircraft at point of origin to reduce predicted congestion
- GDP model maintains arrival list with the latest information for each flight scheduled to arrive at each monitored airport
- Use sliding fixed-length time window in GDP decision algorithm

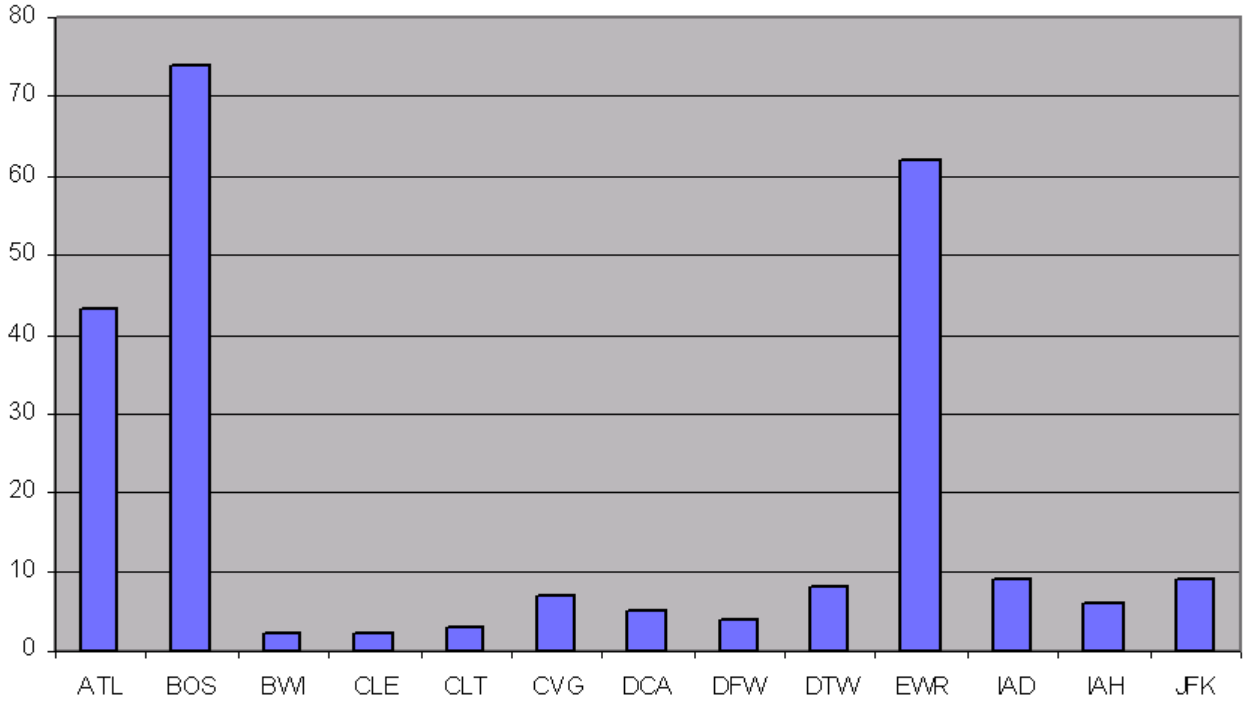


GDP Decision Algorithm Window

ATCSCC GDP

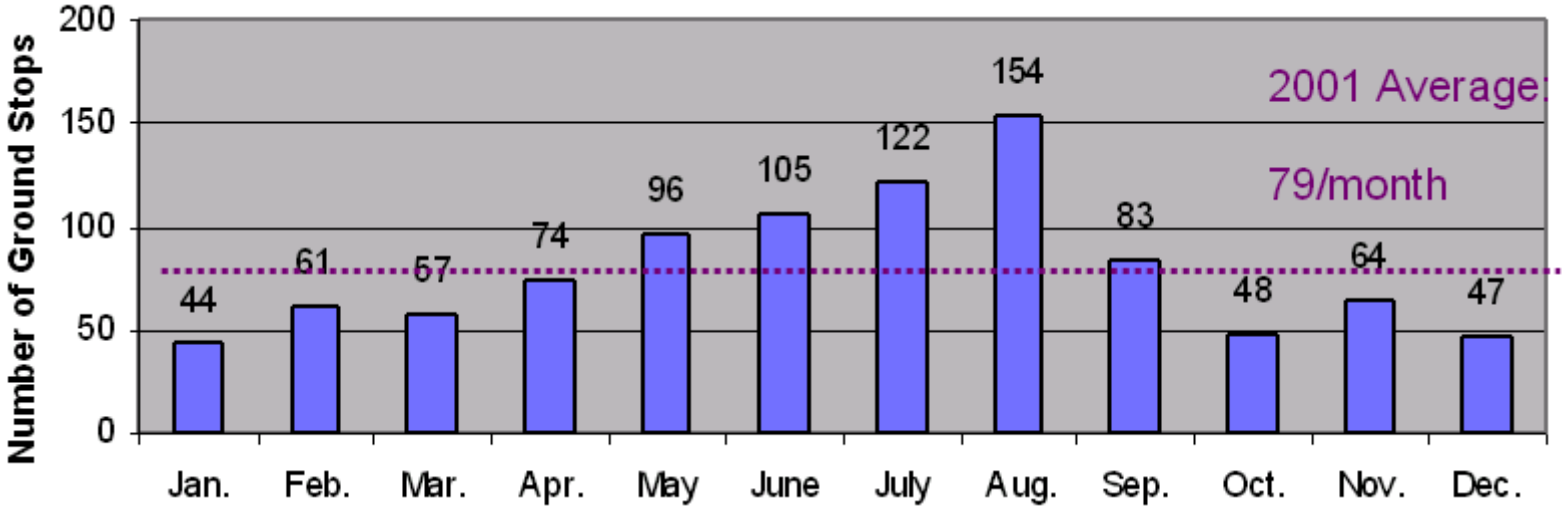
- **Calibrate GDP decision algorithm with historical data**
  - **GDPs have increased in recent years**
  - **GDPs significantly vary with airport**

Year	Number of GDPs	Average per Day*
1998	513	1.4
1999	705	1.9
2000	1083	2.9
2001	799	2.8



ATCSCC Ground Stop

- Ground stop program
  - Similar but simpler than GDP
  - All non exempt arrivals blocked for a time period
    - » Arrival time set to end of time period + 1 minute
  - Convective weather causes more GS activity



ARTCC TFM Requirements

The ARTCC TFM agent shall:

- analyze all predicted congestion events and determine if it can be handled with intra-Center restrictions or if it requires a combination of intra-Center and inter-Center restrictions.
- analyze imposed adjacent ARTCC TFM restrictions and TRACON imposed TFM restrictions, responding with intra and / or inter-Center restrictions
- provide the following data for data collection: Traffic flow restrictions (time issued, time in effect, restriction)

ARTCC TFM

- **Traffic flow restrictions**
  - Model the derivation of traffic flow restrictions to alleviate congestion, including both intra- and inter-Center restrictions
- **Receive congestion alert**
- **Decide whether to take action or not**
  - Consider severity of congestion and effectiveness of flow restriction
- **Decide whether to delay aircraft within facility or to impose restrictions upstream**
- **Model MIT with requested delays**
  - Relatively easy to identify flights to be delayed and desired delay
  - More difficult to implement MIT
  - Requested delay is a good approximation of MIT

ARTCC ATC Requirements

The ARTCC ATC agent shall:

- predict conflicts between aircraft in the en route airspace providing adequate time (TBD) to resolve the conflict
- issue speed or vector advisories to aircraft to comply with conflict resolution and / or TFM constraints.
- deliver aircraft conflict free to adjacent facilities (ARTCC or TRACON)
- provide the following data for data collection: ATC TFM restriction (time issued, time of restriction, AC IDs, action taken); ATC separation action (time issued, time of ATC action, AC IDs, action taken)

ARTCC ATC

- **Meet restrictions and maintain separation**
  - Model the air traffic control of aircraft to adhere to traffic flow restrictions and maintain aircraft separation
- **Delay strategies**
  - Speed control
    - » Use speed reduction if sufficient
  - Path control
    - » Use path stretching when necessary
      - S-turn
- **Maintain separation**
  - Check for loss of separation
  - Use CD&R algorithms to resolve predicted separation loss
    - » ~15 minute prediction horizon
    - » FACET CD&R algorithm a likely candidate

TRACON TFM and ATC Requirements

The TRACON TFM Agent shall:

- utilize a delay distribution function to determine the degree of TRACON delay absorption for delayed arrival aircraft.
- determine arrival and departure flight times through its airspace
- assign scheduled landing times consistent with airport arrival rates.

- Each TRACON shall be represented as a generic TRACON with 4 independent arrival and 4 independent departure meter fixes
- Scheduled TRACON flight times will be nominal flight times dependent on aircraft type.

TRACON TFM and ATC

- **TFM**
  - Manage TRACON-ARTCC boundary crossing traffic flow restrictions at Arrival and Departure Fixes
    - » Receive TFM restrictions (delay per flight) from Airport and ARTCC TFM agents
    - » Pass airport capacity-based restrictions to ARTCC TFM
    - » Pass en route congestion-based restrictions to Airport TFM

- **ATC**
  - Process flights through the TRACON airspace
    - » Access actual takeoff arrival and actual fix crossing times
    - » Compute TRACON flight time for departures and arrivals
    - » Apply minimum separation requirement at Departure Fix
    - » Update/pass scheduled landing times
    - » Update/pass scheduled departure fix crossing times

Airport TFM Requirements

The Airport TFM agent shall:

- send TFM restriction messages to the Airport ATC agent describing delay constraints on scheduled departure flights
- determine the time-varying airport departure and arrival acceptance rates, accounting for meteorological conditions and capacity constraints.
- impose TFM restrictions for arrival flights within the TRACON and to adjacent ARTCCs in response to limited capacity at the airport.
- impose TFM restrictions for departure flights at the airport in response to limited capacity in the adjacent ARTCC.

Airport TFM

- **Assign airport runway arrival and departure acceptance rates based on:**
  - Airport arrival and departure maximum acceptance rates
  - Arrival versus departure loading per flight schedule
  - Current airport queue updates received from Airport ATC agent
- **Determine runway arrival and departure TFM restrictions (delay per flight) to satisfy arrival and departure acceptance rates**
- **Pass arrival and departure acceptance rates to**
  - Airport ATC agent
  - ATCSCC agent
- **Pass Airport-based TFM restrictions to TRACON TFM Agent**
- **Update/Pass scheduled takeoff times in flight data set**
  - ATCSCC ground delay and ground stop delay assignments
  - Departure constraints relayed from to TRACON TFM

Airport ATC Requirements

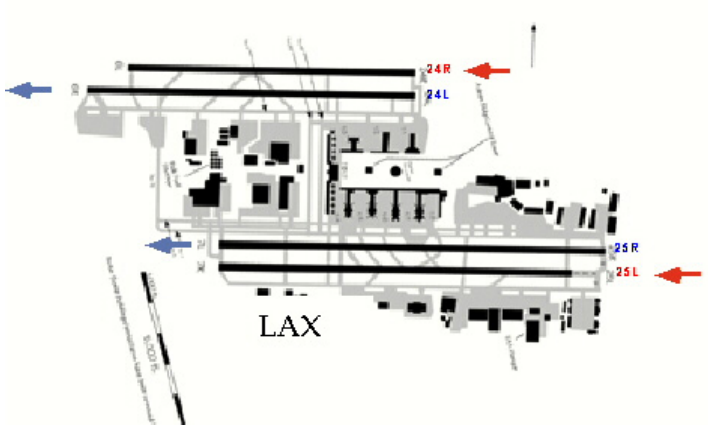
The Airport ATC agent shall:

- revise the departure schedule to accommodate TFM restrictions.
- revise the departure schedule to reflect AOC flight delays and cancellations.
- determine takeoff and landing spacing requirements
- assign actual times of runway departure and arrival time corresponding to the spacing requirements.
- assign actual gate departure times and actual gate arrival times
- maintain data describing runway actual departure and arrival queuing

- Each airport shall be represented by independent arrival and departure traffic flows and arrival and departure capacities

Airport ATC

- **Determine actual runway departure and arrival times**
  - Treat airport as having aggregate departure and arrival capacities
  - Queuing model assigns actual landing and takeoff times
- **Update/Pass actual takeoff and landing time in flight data set**
- **Pass current airport queue updates to Airport TFM agent**



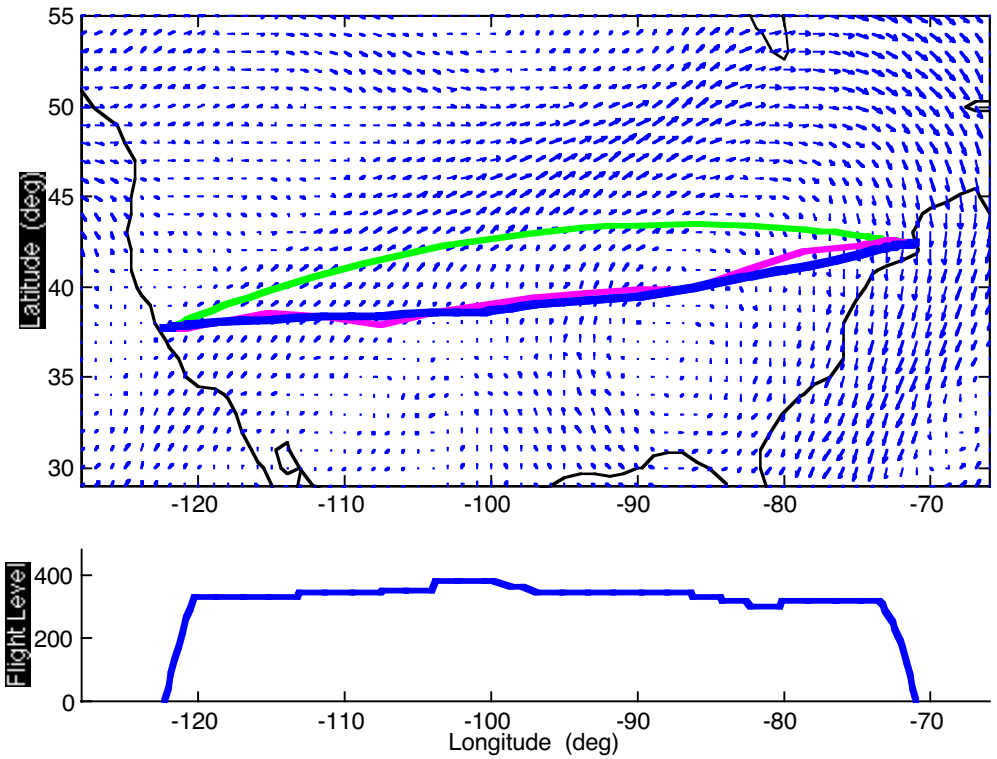
Weather Requirements

The Weather model shall:

- utilize historical wind data sets (e.g. RUC data) to represent truth winds
- interpolate between wind data sets to provide a 4D wind vector
- model inclement weather as capacity reductions of en route airspace or airports

Weather

- **Wind**
  - Use gridded, time-varying data
    - » RUC from January 29, 2002
    - » Use 4D interpolation
- **Heavy weather**
  - Model as temporary capacity reduction
    - » Sectors and airports
  - Will cause traffic delay



AOC/Flight Control Requirements

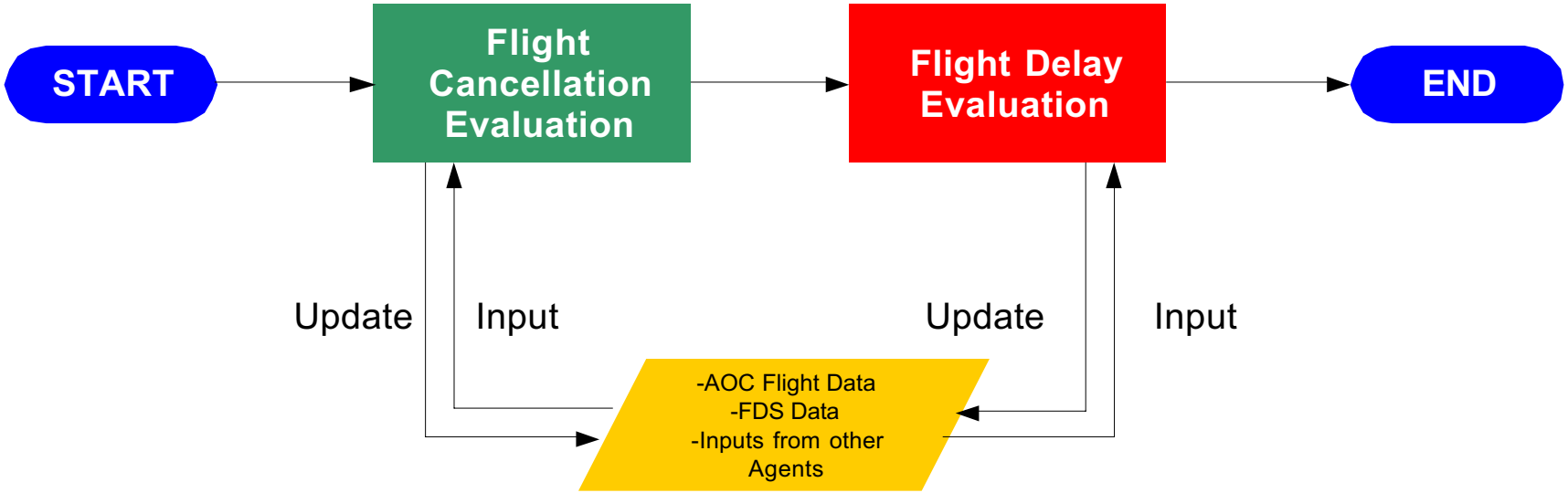
The AOC agent:

- shall cancel flights in high frequency markets when gate departure times exceed a preset time limit.
- shall impose airline induced flight delays to preserve flight connections within preset time limits
- can exhibit different behavior through adjustment of cancelation and delay time limits.

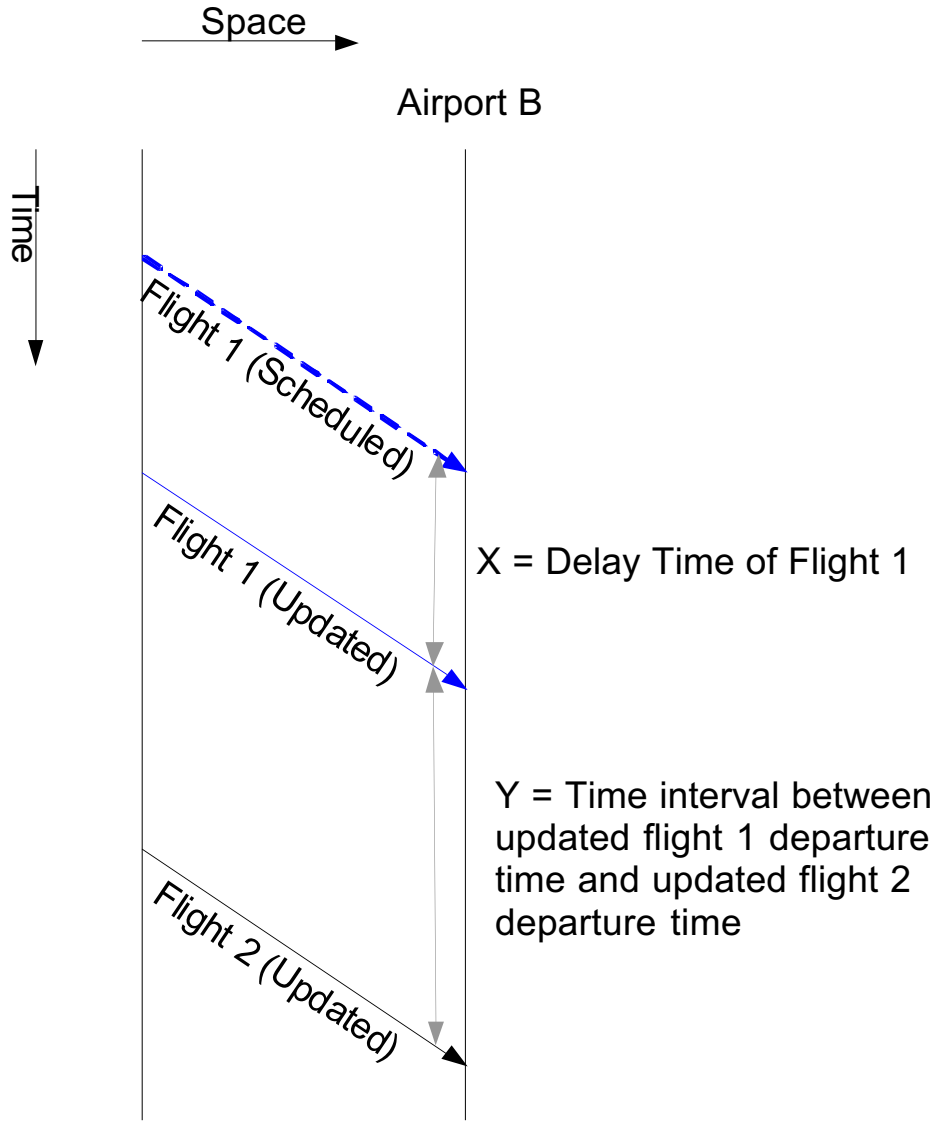
AOC/Flight Control

- AOC real-time flight control
  - Model the airline control of flights
    - » Cancellations
      - Primarily due to extended ATC takeoff delay
    - » Delays
      - E.g., for delayed connecting flights

AOC Real-Time Flight Control Process



Cancellation Algorithm



Cancellation Algorithm

IF

1) X > a pre-set tolerable flight delay time

and

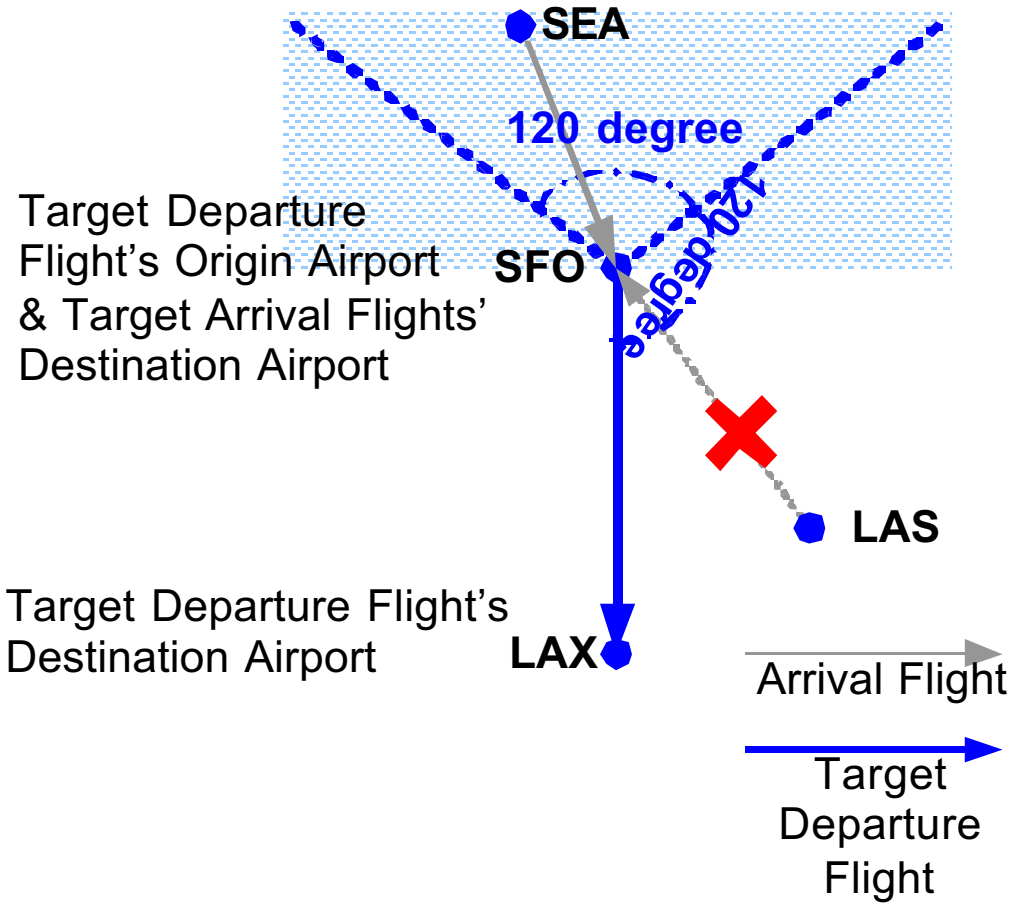
2) Y < a pre-set flight time interval between flight 1 and flight 2

THEN

Cancel Flight 1

Delay Algorithm

Need to Identify the amount of time the Target Departure Flight has to be delayed



IF
the arrival flight's departure airport fall within the shade area

THEN
we identify that the arrival flight as a connecting arrival, which has a passenger connection relationship with the target departure flight

The amount of delay for the target departure flight is the max delay of all connecting arrivals.

e.g. SEA – SFO is a valid connecting arrival for SFO – LAX flight.
LAS – SFO is not a valid connecting arrival for SFO – LAX flight.

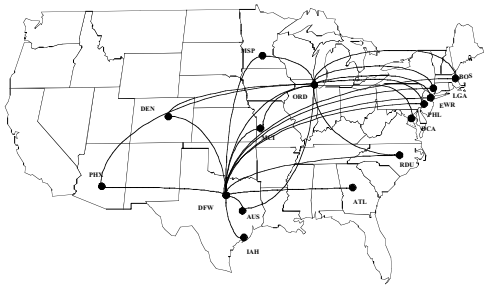
AOC/Traffic Demand Requirements

The traffic demand model shall:

- create a realistic set of scheduled flights using historical data files to represent the current NAS operational environment
- specify a gate-to-gate flight plan
- utilize generic meter fixes for TRACON entry and exit points
- provide the following data: airline, flight ID, departure airport, arrival airport, aircraft type ID, scheduled gate departure time, scheduled runway departure time, scheduled departure meter fix time, scheduled arrival meter fix time, scheduled runway arrival time, scheduled gate arrival time

AOC/Traffic Demand

- Traffic demand model
  - Model traffic demand for a 24 hour period
    - » Each flight described
      - City pair, aircraft type, flight plan, departure time, connection information, etc.
  - Based on historical data
    - » Therefore have realistic traffic patterns and terminal-area loading
  - ~200 biggest airports
  - ~20,000+ flights



Traffic Demand Generation Processes